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March 14, 2006

Captain Peter J. Boynton
Captain of the Port, Long Island Sound
120 Woodward Avenue
New Haven, Connecticut 06512

Subject: Broadwater Energy Project:
USCG Docket USCG-2005-21863
FERC Docket CP06-54

Dear Captain Boynton:

Broadwater Energy is in receipt of the U.S. Coast Guard's letter of February 16, 2006 to Mr. Richard R. Hoffman of the Federal Energy Regulatory Commission (FERC) concerning additional information requirements arising from the Coast Guard's review of Broadwater's Resource Report No. 13. The additional information requested falls into two general categories.

The first request was for a description of the process used to determine which code, rule or standard was applied to the design of the FSRU and yoke mooring system when more than one code or standard was applicable. The second request was for thermal radiation and vapor dispersion calculations for LNG spills based on both accidental and intentional breaches of the cargo tanks for the FSRU and for a LNG carrier of a 250,000 m^3 capacity, which corresponds to the largest carrier size contemplated in Broadwater's future operations.

On February 17, 2006, Broadwater filed a report prepared by Det Norske Veritas (DNV) dated February 13, 2006 which addressed most of the questions raised in prior correspondence from the Coast Guard dated December 21, 2005. At that time, Broadwater noted that the thermal modelling results noted in the Coast Guard's February 16th letter were not available and would be provided at the earliest opportunity. This was acknowledged in the Coast Guard's letter of February 21, 2006.

In response to the Coast Guard's February 16, 2006 letter to FERC, Broadwater encloses two reports:

1. A report by Det Norske Veritas dated March 10, 2006, which provides the thermal radiation results for accidental and intentional breaches of the FSRU and LNG carrier cargo tanks.

2. A report summarizing the process used by Broadwater to establish the codes and standards which were applied to the design of the FSRU and yoke mooring system. The precise codes and standards applied to the facility design are documented in Resource Report No. 13. The attached report also provides a discussion of the design of the yoke mooring system relative to the Saffir-Simpson Hurricane Scale.

We trust that these reports provide the information you have requested and will facilitate establishment of the project review schedule by the FERC.

If there are any questions concerning the above or the attached report, please contact Mr. David Thomson of Broadwater at 713-241-8931.

Very truly yours,

Lawrence G. Acker
Brett A. Snyder
Counsel for Broadwater

cc:
Lieutenant Commander Alan Blume
Chief of the Prevention Department, Long Island Sound

James Martin
Federal Regulatory Energy Commission

Ms. Magalie R. Salas
Federal Regulatory Energy Commission

Cooperating Agencies

DNV CONSULTING

Broadwater Fire Modeling:

Report for TransCanada PipeLines Limited
Report no.: 70015341
Rev 1, 10 March 2006

MANAGING RISK

Broadwater Fire Modeling

for

TransCanada PipeLines Limited
450 - 1st Street S.W.
T2P 5H1 Calgary, Alberta
CANADA

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Client ref: Captain David Thomson

Report No.: 70015341 Subject Group:

Indexing terms:

Summary: This study will mainly focus on thermal hazard zones from pool fires due to immediate ignition to supplement the previous DNV Report, ref. 03, which focused on the thermal hazard zones from vapor cloud dispersion with late ignition.

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Date of issue: 10 March 2006

Project No: 70015341

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Contents:

1.0 Introduction

As part of the permitting process for Broadwater Energy's (henceforth, Broadwater) proposed Floating Production, Storage and Regasification Unit (FSRU) in Long Island Sound, the United States Coast Guard (USCG) in February of 2006 issued a letter (ref.01) requesting thermal radiation analysis for accidental and intentional breaches (as defined by Sandia, ref.02). In response, Broadwater requested that Det Norske Veritas (USA), Inc. (DNV) respond to the USCG based on DNV's risk analysis experience with LNG terminals.

This study will mainly focus on thermal hazard zones from pool fires due to immediate ignition to supplement the previous DNV Report, ref. 03, which focused on the thermal hazard zones from vapor cloud dispersion.

2.0 Objective

The objective of this study is to provide site specific thermal hazard zones resulting from pool fires for the hole sizes defined by Sandia, ref.02, for both intentional and accidental breaches, using the DNV software PHAST v6.42. This study will also compare the site specific and model specific parameters used as the basis for the results with the parameters used in the Sandia study. In addition, this study also documents dispersion results for a $0.5m^2$ hole to further supplement the results from previous vapor cloud dispersion analysis, as documented in the previously issued DNV report, ref. 03.

3.0 Consequence Modeling Basis

The following section covers the basis for the DNV consequence modeling and includes discussions on cargo tank volumes, volume released, LNG head above the breach, and weather conditions.

3.1 Site Specific LNG Spills

The DNV consequence modeling is based on site specific information while the Sandia study is based on generic data. The release rate is largely dependent on the amount of LNG head above the breach. A breach in both the FSRU and LNG carrier has been assumed to occur just above the water line. This assumption results in the largest LNG head and release volume, and consequently the most conservative results. A simplification of the LNG head in a tank is illustrated in Figure 3-1.

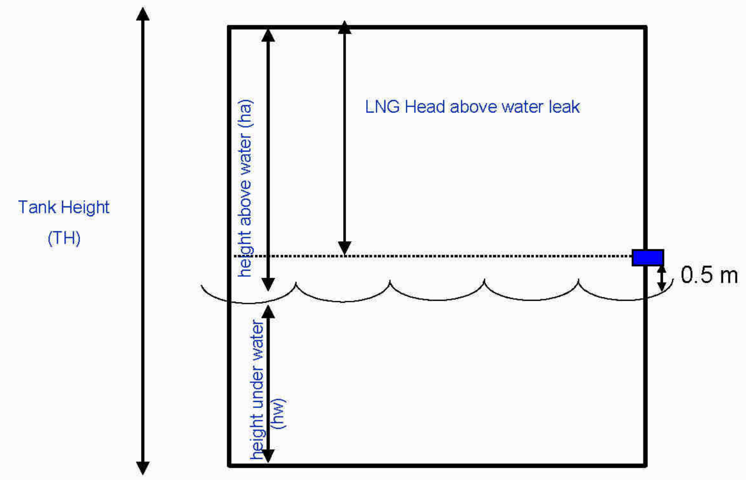

Figure 3-1 LNG Head above Water Leak

The Broadwater project is currently considering an FSRU with eight cargo tanks that each holds a volume of approximately 45,000 m^3 of LNG. The LNG carriers that unload at the Broadwater facility may vary in size. This study attempts to be conservative in its assumptions; therefore, one of the largest sized carriers was chosen as a base case (250,000 m^3 carrier with six storage tanks). The tank volumes, release volumes and LNG head that have been used as the basis for the Broadwater site specific evaluations are presented in Table 3-1, together with the data use in the Sandia study for comparison purposes.

Table 3-1 Consequence Modeling Input

Consequence Input	Sandia	Broadwater FSRU	Broadwater LNG Carrier
Tank Volume (m^3)	25, 000	44, 850	42, 000
Release Volume (m^3) (above water release)	12, 500	35, 560	27, 300
LNG Head (m)	15	21	20.3
Draft (fully loaded) (m)	Not Specified	12.3	12

In order to be conservative on the amount of cargo tank volume released, it is assumed that the FSRU tanks are 98% full. This will be the case just after being visited by an LNG carrier. The LNG carrier cargo tanks are assumed to be 95% full.

As can be seen from Table 3-1, Sandia assumed that 50% of the LNG cargo tank volume would be released during a spill. DNV calculated the site specific release volumes based on the amount of draft when the vessel is fully loaded and the LNG head above the release. This resulted in a larger release volume than assuming a uniform 50% of the volume is released.

There is uncertainty within the industry on determining total release volume for a large LNG leak. This is due to a number of phenomenon that are difficult to determine for such large scale leaks, such as possible water ingress into the tank, LNG or water ingress into the space between the inner and outer hulls, cryogenic effects on the tanker hull, etc.

The DNV site specific release volumes are larger than Sandia's for two reasons:

1. The Broadwater LNG carrier cargo tanks and the FSRU cargo tanks are larger than the cargo tanks considered by Sandia.
2. The DNV approach used to calculate site specific release volumes is more conservative than the approach used in the Sandia study.

Also, it is assumed that all released materials will be spilled outside the FSRU or LNG carrier into the environment.

Previously documented collision vulnerability analysis, ref. 03, indicates that the larger LNG carriers are less vulnerable to collision damage than smaller sized (current generation) LNG carriers, given the same impact energies, predominantly as a result of the increased separation distance between the inner and outer hulls. The Sandia Report breach sizes are based on smaller LNG carriers and are therefore conservatively (based on equal impact energies) applicable to the proposed Broadwater FSRU and LNG carriers.

3.2 Site Specific Meteorological Conditions

Based on the site specific weather data received from the National Climatic Data Center (NCDC), the three most common combinations of wind speed and stability class were determined. These three representative weather conditions for the Broadwater study are presented in Table 3-2 (see ref. 03)

Table 3-2 Representative Weather Conditions

Stability Class	Average Wind Speed	Percent of Day
F	2 m/s	15%
D	3.5 m/s	49%
D	7 m/s	21%

Other meteorological conditions include the following assumptions:

- Relative Humidity – 70% (recommended for releases over open water)
- Temperature – 20 •C
- Surface Roughness Length – 0.3 mm (roughness length of open sea)

3.3 Pool Fire Parameters

This section discusses some of the key parameters that have a significant impact in the LNG pool fire consequences. Also, the parameters used by DNV and Sandia, respectively, are compared in ref. 05 (attached as Appendix I).

3.3.1 Hole Size

The hole sizes of accidental ($1m^2$ and $2m^2$) and intentional ($5m^2$) breaches are the same as applied in the Sandia Report, ref. 02. In addition, a $0.5m^2$ breach is studied to further supplement the results from previous vapor cloud dispersion analysis, as documented in the previous DNV report, ref. 03.

As previously documented in ref. 03, the FSRU and larger (future generations of) LNG carriers are expected to experience smaller breach sizes than smaller LNG carriers (currently in service) given the same impact energies, The Sandia study breach sizes are based on smaller LNG carriers and are therefore conservatively applicable (based on equal impact energies) to the proposed Broadwater FSRU and LNG carriers.

3.3.2 Discharge Coefficient

The DNV model approach documented in this study and Sandia, ref. 02, use a similar approach for discharge modeling. The Bernoulli equation (Eqn. 1) was used to estimate the discharge rate through the hole. DNV and Sandia use the same discharge coefficient of 0.6.

$$Q = C_d A \bullet [2 (P_i - P_o) / \bullet\bullet + 2gH]^{0.5} \quad \text{(Eqn. 1)}$$

Where: P_i = LNG vapor space pressure
H = LNG liquid head
P_o = Atmospheric Pressure

3.3.3 Burning Rate

The burning rate is a critical parameter in pool fire modeling since it determines the amount of material which burns per unit area and per unit time. Table 3-3 shows the burning rates used by DNV and Sandia, respectively. DNV uses a corrected burning rate for pool fires occurring over water, while Sandia has no indication of a correction for releases over water.

Table 3-3 Burning Rate Over Water

Study	Burning Rate ($kg/m^2/s$)	Reference
DNV	0.353	Cook et al. 1990
Sandia	0.128	Not provided

The burning rate of methane on land is known to be 0.141 $kg/m^2/s$. In case of fires on the water surface, the burning rate increases due to heat transfer from water. According to Cook et al. ref. 04, the burning rate on water is 2.5 times greater than the burning rate on land.

3.3.4 Surface Emissive Power

The Surface Emissive Power (E) is the energy that is radiated per unit surface at the surface of the fire. The intensity of thermal radiation (Q) that an individual may receive from a pool fire is directly proportional to the surface emissive power (E):

$$Q = E F \bullet\bullet \quad \text{(Eqn. 2)}$$

where E is the Surface emissive power, F is the Geometrical view factor and ••is the transmissivity of atmosphere. DNV and Sandia used the same surface emissive power of 220kW/m^2.

3.3.5 Pool Radius

Pool radius and burning rate are competing factors. If the burning rate is higher, then the pool size would be smaller and vice versa. The size of the pool and the burning rate both have direct effect on the predicted thermal radiation levels and hazard distances and are very critical parameters in pool fire modeling.

The Sandia study uses a lower burning rate compared to the DNV approach. However, Sandia uses the same pool size for ignited pools and un-ignited pools, while DNV calculates larger pool sizes for an un-ignited pool compared to an ignited pool. The pool fire results in this study are based on pool size from an ignited pool.

4.0 Consequence Modeling Results

4.1 Vapor Cloud Dispersion

The results for dispersion modeling as documented in the previous DNV report, ref.03, along with results for the additional 0.5m^2 (800 mm) hole are given in Table 4-1.

Table 4-1 Vapor Cloud Dispersion Modeling Results

	Distance to LFL (m)						
Hole Size (mm)	**Sandia**	**FSRU**			**LNG Carrier**		
	F 2.33 m/s	**F 2 m/s**	**D 3.5 m/s**	**D 7 m/s**	**F 2 m/s**	**D 3.5 m/s**	**D 7 m/s**
800 (0.5 m^2)		1430 m	785 m	825 m	1410 m	780 m	820 m
1120 (1 m^2)	1536 m	1870 m	1030 m	1100 m	1890 m	1020 m	1090 m
1600 (2 m^2)	1710 m	2280 m	1390 m	1570 m	1990 m	1370 m	1560 m
2523 (5 m^2)	2450 m	3320 m	2050 m	2360 m	3290 m	2030 m	2340 m

The results for vapor cloud dispersion modeling were discussed in the previous DNV report, ref.03.

4.2 Pool Fires

The extent of personal injury due to thermal radiation is determined by the radiation exposure level duration and type of personal protection. Radiation levels resulting from a specific pool fire are a function of distance from the pool. The further away from the fire, the lower the thermal radiation levels. DNV presents three thermal radiation levels whereas Sandia presents results for only 5 kW/m^2 and 37.5 kW/m^2. The general type of thermal radiation damage from a fire is discussed as following:

37.5 kW/m² – (Immediate effects)
It is assumed to result in immediate fatality for all exposed persons and possible damage to structures and equipment.

12.5 kW/m² – Exposure time of up to 1 minute
This heat load can result in pain after 4 seconds and a high level of pain within 20 seconds. Second degree burns and burns which may result in death can occur after approximately 40 seconds. Generally used in risk analysis to determine impact on populations.

5 kW/m² – Exposure time for up to 10 minutes
This heat load can result in pain after 16 seconds. Normal work clothing would protect for several minutes. It is generally assumed escape is possible.

People located indoors or within sheltered areas will obtain additional protection against heat loads, the extent of which is dependent on the structure and composition of the protected areas, such as the building material, windows, etc.

The thermal radiation distances resulting from pool fires, as presented in Table 4-2 and Table 4-3, are measured from the center of the pool (point of release). Also, the thermal radiation levels and distances documented in the Sandia report, ref.02, are listed for comparison.

Table 4-2 FSRU Pool Fire Modeling Results

		FSRU Fire Modeling									
Hole Size (mm)	Sandia (m)	Distance to 5 kW/m² (m)			Distance to 12.5 kW/m² (m)			Sandia (m)	Distance to 37.5 kW/m² (m)		
	F 2.33 m/s 5 kW/m²	F 2m/s	D 3.5 m/s	D 7 m/s	F 2m/s	D 3.5 m/s	D 7 m/s	F 2.33 m/s 37.5 kW/m²	F 2m/s	D 3.5 m/s	D 7 m/s
800 (0.5 m²)	-	470	484	507	303	330	357	-	148	172	210
1120 (1 m²)	554	606	629	655	392	425	462	177	193	222	270
1600 (2 m²)	784	797	826	858	515	557	604	250	255	292	354
2523 (5 m²)	1305	1127	1167	1211	730	786	852	391	366	415	498

Table 4-3 LNG Carrier Pool Fire Modeling Results

		LNG Carrier Fire Modeling									
Hole Size (mm)	Sandia (m)	Distance to 5 kW/m² (m)			Distance to 12.5 kW/m² (m)			Sandia (m)	Distance to 37.5 kW/m² (m)		
	F 2.33 m/s 5 kW/m²	F 2m/s	D 3.5 m/s	D 7 m/s	F 2m/s	D 3.5 m/s	D 7 m/s	F 2.33 m/s 37.5 kW/m²	F 2m/s	D 3.5 m/s	D 7 m/s
800 (0.5 m²)	-	466	482	504	301	329	356	-	147	171	209
1120 (1 m²)	554	602	624	650	389	423	459	177	191	221	269
1600 (2 m²)	784	791	820	852	511	553	600	250	253	290	352
2523 (5 m²)	1305	1120	1160	1202	725	780	846	391	363	411	495

As can be seen from the results above, the effects of wind speeds and stability class on the thermal radiation distances are not significant. The LNG carrier results are slightly lower than FSRU results, because the LNG carrier has a smaller liquid head and therefore smaller discharge rate.

The largest pool fire radiation ellipse (5 kW/m^2) resulting from spill from the LNG carrier is calculated to be 1202 m (0.7 mile). The closest passage of the LNG carrier to land is at the race where the carrier will be approximately within 1610 m (1mile) from shore. The largest pool fire radiation distance resulting from spill from the FSRU has been calculated to extend 1211 m (0.7 miles) while the closest land is approximately 14,500 m (9 miles).

The duration of a pool fire depends on hole size, release rate, burning rate and volume released. The durations of the pool fires presented in Table 4-2 and Table 4-3 are expected to be within the interval of approximately 15 minutes for the 5m^{2,} hole size to approximately 1.5 hours for the 0.5m^2 hole size.

Comparing with Sandia results, the radiation distances in Table 4-2 and Table 4-3 are slightly larger for accidental breaches, but shorter for intentional breach (2523 mm hole). A sensitivity study was carried out to investigate the effects of parameters on radiation distance.

4.3 Sensitivity Analysis

As discussed in Section 3.3, the major difference in the parameters used by DNV and Sandia is the burning rate over water. A sensitivity analysis is carried out by using the same burning rate as used in the Sandia study (0.128 kg/m^2/s). Table 4-4 and Table 4-5 show the thermal radiation distances resulting from pool fires using a burning rate of 0.128 kg/m^2/s. Also, the radiation results as documented in the Sandia study, ref.02, are listed for comparison.

Table 4-4 FSRU Pool Fire Modeling Results – Sensitivity Analysis

		FSRU Fire Modeling									
Hole Size (mm)	Sandia (m)	Distance to 5 kW/m^2 (m)			Distance to 12.5 kW/m^2 (m)			Sandia (m)	Distance to 37.5 kW/m^2 (m)		
	F 2.33 m/s 5 kW/m^2	F 2m/s	D 3.6 m/s	D 7 m/s	F 2m/s	D 3.6 m/s	D 7 m/s	F 2.33 m/s 37.5 kW/m^2	F 2m/s	D 3.6 m/s	D 7 m/s
800	-	529	539	549	358	374	389		205	229	258
1120	554	689	701	715	467	488	505	177	269	297	335
1600	784	910	924	944	618	644	666	250	358	393	441
2523	1305	1297	1318	1344	885	919	953	391	518	563	629

Table 4-5 LNG Carrier Pool Fire Modeling Results – Sensitivity Analysis

		LNG Carrier Fire Modeling									
Hole Size (mm)	Sandia (m)	Distance to 5 kW/m^2 (m)			Distance to 12.5 kW/m^2 (m)			Sandia (m)	Distance to 37.5 kW/m^2 (m)		
	F 2.33 m/s 5 kW/m^2	F 2m/s	D 3.6 m/s	D 7 m/s	F 2m/s	D 3.6 m/s	D 7 m/s	F 2.33 m/s 37.5 kW/m^2	F 2m/s	D 3.6 m/s	D 7 m/s
800	-	526	536	546	356	373	387		205	228	257
1120	554	684	696	710	464	484	502	177	267	295	333
1600	784	904	918	938	614	640	662	250	355	390	438
2523	1305	1288	1308	1335	878	913	946	391	514	559	624

The results from the sensitivity analysis show a slight increase in hazard distances compared to the base case results. This trend is expected because larger steady state pools will be generated with a smaller burning rate.

There are many uncertainties for modeling large pool fires, especially for intentional breaches, because there is no large-scale experimental testing available to validate the theoretical models. The Sandia Report (Section 5.5.1, page 51, last paragraph) discusses that for large pool fires, it is expected that they will break up into smaller pool fires because the center of the pool will not have enough oxygen to burn. The pool will then break up into "flamelets" which will have shorter flame heights and diameters and thus smaller radiation ellipses. This report has not modeled pool fire break-up but assumed a conservative large pool fire.

5.0 Conclusions

Previously documented collision vulnerability analysis, ref. 03, indicates that the larger LNG carriers are less vulnerable to collision damage than smaller sized (current generation) LNG carriers. Hence, the smaller LNG carriers are expected to experience larger breach sizes than larger LNG carriers if they are exposed to the same impact energy. The Sandia breach sizes are based on smaller sized LNG carriers (capacity of 125,000 m^3) and are therefore conservatively (given the same impact energy) assumed to be applicable for larger sized LNG Carriers and the FSRU.

Both DNV and Sandia recommend a risk based approach which includes consequence calculations along with frequency estimates to determine overall risk for specific scenarios. This report only presents consequence evaluations.

The hazard zones presented in this report are based on the hole sizes that Sandia concludes are representative for accidental and intentional acts combined with site specific weather data and worst case spill volumes for future generations of LNG carriers and the FSRU. Frequencies for the various scenarios have not been addressed in this study.

It can be concluded that the Broadwater site specific radiation distances from accidental breaches are slightly larger compared to the radiation distances documented in the Sandia study, but shorter for intentional breach (2523 mm hole). The difference in the Sandia and the Broadwater site specific results performed by DNV is believed to be within the margin of uncertainty for both Sandia's CFD model and DNV's PHAST model.

The largest pool fire radiation ellipse (5 kW/m^2) resulting from spill from the LNG carrier is calculated to be 1202 m (0.7 mile). The closest passage of the LNG carrier to land is at the race where the carrier will be approximately within 1610 m (1mile) from shore. The largest pool fire radiation distance resulting from spill from the FSRU has been calculated to extend 1211 m (0.7 miles) while the closest land is approximately 14,500 m (9 miles).

6.0 References

01 U.S. Coast Guard letter to Broadwater Energy, dated February 21st, 2006, no. 16211/06-119, written by Peter J. Boynton of the U.S. Coast Guard.

02 "Guidance on Risk Analysis and Safety Implications of a Large Liquefied Natural Gas (LNG) Spill Over Water," Sandia Report SAND2004-6258, Sandia National Laboratories, December 2004.

03 DNV Report, "Broadwater LNG: Response to U.S. Coast Guard Letter Dated December 21, 2005," Report no. 70014347 ,Rev. 1 February 13, 2006.

04 Cook, J., Bahrami, Z., Whitehouse, R. J., "A comprehensive program for calculation of flame radiation levels", J. Loss Prev. Process Ind., 3, pp 150-155, 1990

05 "Consequence Modeling of LNG Marine Incidents," paper prepared by Baik, John; Raghunathan, Vijay; Witlox, Henk, to be presented in March 2006 at American Society of Safety Engineers conference. Attached as Appendix I

06 "LNG Marine Release Consequence Assessment," Joint Sponsor Project, April 21, 2004, DNV report no. 70004197.

Appendix I – Consequence Modeling of LNG Incidents

American Society of Safety Engineers
Middle East Chapter
7th Professional Development Conference & Exhibition
Kingdom of Bahrain, March 18-22, 2006

CONSEQUENCE MODELING OF LNG MARINE INCIDENTS

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Abstract

The LNG consequence analysis studies related to marine incidents are gaining prominence in the U.S. and some other countries due to the potential increase in LNG trade in the near future. To address the issues of LNG hazards associated with marine transportation, many safety assessment studies have been performed by various companies and organizations. These recently conducted studies related to LNG employ different methodologies and have published varying results. The disparity in results is mainly due to the difference in release sizes, modeling parameter assumptions and modeling tools used in calculating the hazard zone.

This paper reviews the modeling approaches used by different companies and organizations. A detailed discussion on critical modeling parameters and assumptions affecting the consequence analysis results are also presented in this paper.

Keywords: LNG, consequence modelling

1. INTRODUCTION

There has been substantial debate in the U.S. over the potential consequences of a marine accident involving an LNG vessel at or approaching one of the four current U.S. import terminals or one of the up to 45 proposed new terminals in North America. This debate has occurred at public meetings associated with the approval process, in conferences, and published technical papers. Some recent publications on this topic include: Quest (Cornwell, 2001), Fay (Fay, 2003), ABS (ABS, 2004), DNV (Pitblado et al., 2004) and Sandia (Hightower et al., 2004).

The hazard zone distances reported from the above studies are quite varying. The disparity in results is due to the difference in release sizes, modeling parameter assumptions and somewhat due to modeling tools used in calculating the hazard zone distances. DNV and Sandia studies have a stronger basis for the hole size selection, while other studies do not provide the basis for the hole size selection. ABS used the discharge coefficient of 1.0 in estimating the release rate, while DNV and Sandia used 0.6 for discharge coefficient. Therefore, ABS's result is a conservative one.

There are many other critical parameters that affect the consequence modeling results. Investigation of these critical parameters provides better understanding and confidence on the results reported by different companies and organizations. This paper provides detailed discussions on the modeling approaches used by ABS, DNV, Sandia and Quest. The study done by Fay is excluded since the detail parameters used in the modeling are not available.

2. RESULTS OF RECENT STUDIES

The four recent studies reviewed in this paper are:

- DNV - A Joint Sponsor Project that involved a credible risk assessment approach of marine LNG release scenarios subject to external peer review.
- ABS - Federal Energy Regulatory Commission (FERC) sponsored this study with the goal of estimating flammable vapor and thermal radiation hazard distances for potential LNG cargo releases.
- Sandia - A work sponsored by the U.S. Department of Energy that provides guidance on appropriateness of models, assumptions and risk management to address

public safety relative to a potential LNG spill over water.

- Quest - Quest Consultants Inc. provided a letter to the U.S. Department of Energy regarding the consequence of a potential release of LNG from a ship.

More details on the above studies including adopted modeling tools are given in Section 3. The latter section also includes further details of the modeling approaches for LNG discharge onto water, subsequent pool spreading/evaporation, the pool fire (case of ignition) and vapor cloud dispersion (case of no ignition).

The consequence results analyzed in this paper include:

- Thermal radiation hazard zones – distance to 5 kW/m^2 and 37.5 kW/m^2
- Flammability hazard zone – distance to LFL

Pool Fire Results

The pool fire radiation results from the above mentioned studies are presented below in Table 1 and also in the form of a graph in Figure 1 and Figure 2.

Hole size (mm)	Study	Pool Radius for Radiation (m)	Burning Rate (kg/m^{2}s)	Radiation Distance	
				5 kW/m^2	37.5 kW/m^2
250	DNV	15	0.353	194 m	70 m
750	DNV	43	0.353	451 m	169 m
1000	ABS	74	0.282	860 m	370 m
	Quest	n/a	0.089	433 m	n/a
1120	Sandia	74	0.128	554 m	177 m
1500	DNV	86	0.353	761 m	289 m
1600	Sandia	105	0.128	784 m	250 m
2523	Sandia	165	0.128	1305 m	391 m
5000	ABS	130	0.282	1400 m	600 m
	Quest	n/a	0.089	540 m	n/a

Table 1. Pool Fire Results

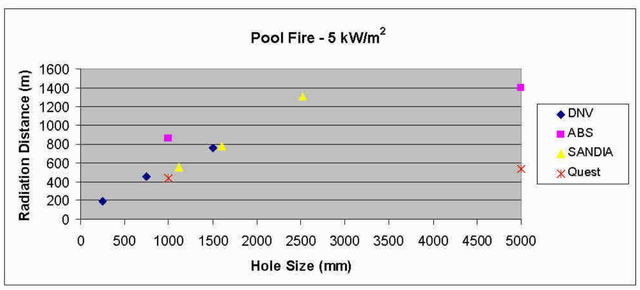

Figure 1. Pool Fire Results – 5 kW/m^2

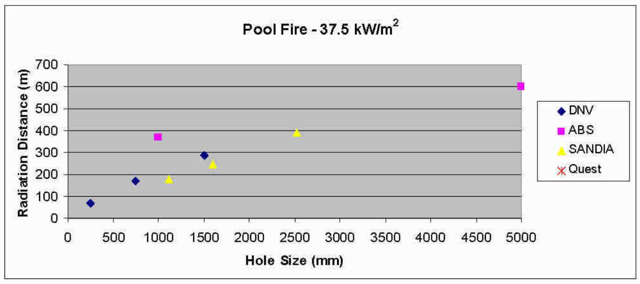

Figure 2. Pool Fire Results - 37.5 kW/m^2

As shown in Table 1, Figure 1 and Figure 2, each study used different hole sizes for their analysis. Therefore, a direct comparison of results is not possible.

Dispersion Results

The pool spreading/evaporation and dispersion results for all four cases are summarized below in Table 2 and also presented graphically in Figure 3. The graph shown below compares only the results for F stability and 2 m/s atmospheric conditions for all four studies, as Sandia provides the dispersion results only for that condition.

Hole size (mm)	Study	Pool Radius for dispersion (m)	Evaporation Flux (kg/m2s)	LFL distance (m)		
				F-2 m/s	D-3 m/s	D-5 m/s
250	DNV	29	0.179	790 m	370 m	380 m
750	DNV	59	0.179	1800 m	850 m	870 m
1000	ABS	130	0.072	3300 m	2000 m	n/a
	Quest	n/a	0.2	3733 m*	n/a	783 m
1120	Sandia	74	n/a	1536 m*	n/a	n/a
1500	DNV	117	0.185	3400 m	1600 m	1700 m
1600	Sandia	105	n/a	1710 m*	n/a	n/a
2523	Sandia	165	n/a	2450 m*	n/a	n/a
5000	ABS	170	0.075	3900 m	n/a	n/a
	Quest	253	0.2	4076 m*	n/a	1002 m

* Sandia and Quest modeled with F-2.33, F-1.5 respectively instead of F/2

Table 2. Dispersion Results

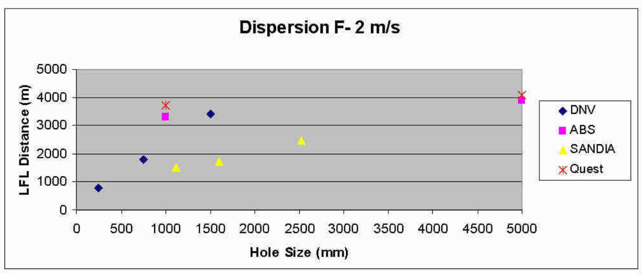

Figure 3. Dispersion Results for F stability and 2 m/s

Similar to the pool fire case, each study used different hole sizes for their analysis as shown in Table 2 and Figure 3. Therefore, a direct comparison of results is not possible.

3. CRITICAL PARAMETERS AFFECTING CONSEQUENCE RESULTS

The purpose of this paper is to analyze the results of the different studies based on the critical parameters affecting the consequence results. There are many parameters that could impact the final results. This paper will discuss the key modeling parameters used in each study and the significance of those key parameters on the consequence results.

The consequence models used for dispersion analysis in the four studies are listed as follows:

- DNV - PHAST
- ABS - DEGADIS
- Quest - CANARY
- Sandia - VULCAN

Of the four different studies, only Sandia used a CFD code (VULCAN) while others used similarity models. Both types of models are known to be adequate for modeling of dispersion over flat terrain.

For pool fire modeling, DNV, ABS and Quest used similar solid flame models, while Sandia used a CFD code, VULCAN.

3.1 Discharge Modeling

As shown in the tables and figures in Section 2, each study used different holes sizes for consequence modeling. Therefore, a direct comparison of the results is not possible. In general, DNV and Sandia studies have a stronger basis on the selection of hole sizes, while ABS and Quest studies used hole sizes selected purely based on the judgement. DNV determined the credible hole sizes based on the collision damage graph from IMO/MARPOL and Sandia determined the holes sizes based on the finite element modelling of ship collisions.

The discharge modeling for each study was performed using a similar approach. Bernoulli's equation was used in all these studies to estimate the discharge rate through the hole. However, the discharge coefficient used in the calculation was quite different.

Bernoulli Equation

$$Q = C_d A \bullet [2 (Pi-Po)/\bullet\bullet + 2gH]^{0.5}$$

Where C_d is the discharge coefficient, A is the hole area, • • the LNG liquid density, P_i is the storage pressure at the top of the LNG liquid, H is the LNG liquid head above the release height and P_o is the atmospheric pressure.

Table 3 shows the discharge coefficient C_d used in each study.

Study	Discharge Coefficient (C_d)
DNV	0.6
ABS	1
Sandia	0.6
Quest	n/a

Table 3 Discharge Coefficient Used in Each Study

As shown in Table 3, ABS used a discharge coefficient of 1.0, while DNV and Sandia used 0.6. The discharge coefficient of 0.6 and 1.0 represents a sharp-edged orifice (TNO, 1999) and a perfect discharge without any restriction, respectively. The ABS discharge rate was 40% greater than DNV and Sandia studies. This may be one of the reasons why the ABS result is more conservative than others. The information on discharge coefficient was not available from the Quest study.

3.2 Pool Fire Parameters

Some of the key parameters that have a significant impact in the LNG pool fire modeling have been identified to analyze the radiation hazard distance results published in these four studies.

Burning Rate

The burning rate is a critical parameter in pool fire modeling since it determines the amount of material which burns per unit area and per unit time. A higher burning rate provides a higher thermal radiation result. Table 4 shows the burning rates used in each study.

Study	Burning Rate ($kg/m^2/s$)	Reference
DNV	0.353	Cook et al. 1990
ABS	0.282	Rew 1996
Sandia	0.128	Not provided
Quest	0.089	Not Provided

Table 4 Burning Rate Values

The burning rate of methane on land is known to be 0.141 $kg/m^2/s$. In case of fires on the water surface, the burning rate increases due to heat transfer from water. According to Cook et al. (1990), the burning rate on water is 2.5 times greater than the burning rate on land.

The DNV and ABS studies used a corrected burning rate in the pool modeling, while others had no indication of those corrections.

Surface Emissive Power

The Surface Emissive Power (E) is the power that is radiated per unit surface at the surface of the fireball. The intensity of thermal radiation (Q) that an individual may receive from a pool fire is directly proportional to the surface emissive power (E):

Q = E F ••

where E is the Surface emissive power, F is the Geometrical view factor and •• is the transmissivity of atmosphere.

Table 5 summarizes the surface emissive power used in different studies and values obtained from LNG pool fire experiments.

Study	Surface Emissive Power (kW/m^2)
ABS	265
DNV	220
Sandia	220
Quest	Not available
USCG China Lake tests	220 ± 30
Maplin Sands	178 to 248

Table 5. Surface Emissive Power Values

As shown in Table 5, the ABS study used higher values than other studies. This can be a part of the reason why the ABS result is more conservative than others.

Pool Radius

Pool radius and burning rate are competing factors and if the burning rate is higher, then the pool size would be smaller and vice versa. The size of the pool has a direct effect on the predicted hazard distances and is very critical in pool fire modeling.

The pool size of an ignited pool is much smaller than that of an un-ignited pool due to the termination of pool spreading upon ignition. Therefore, the pool size needs to be corrected for an ignited pool. The simplest way of correcting the pool size is to use a burning rate assuming a steady state pool.

The DNV and ABS studies used similar approaches in correcting the pool size for hazard distance calculation of pool fires. However, Sandia used the same pool size for ignited pools and un-ignited pools. The information about the pool size is not available in the Quest study.

Wave Effect

The presence of waves on water will affect the spreading of LNG on its surface. The Quest study has incorporated this wave effect by using a conditional statement at the boundary of the pool; namely, the pool will stop spreading once the LNG drops below 60% of the wave height. Therefore, the wave effect would decrease the pool radius as the wave breaks the liquid pool formed on the surface and results in reduced thermal radiation hazard zone. This could possibly explain why Quest reported smaller thermal radiation hazard zone results compared to other studies.

Atmospheric Conditions

Atmospheric wind speed also has an effect on the predicted hazard distances in the case of pool fire modeling. The worst case atmospheric conditions for pool fires are during high winds. The wind allows the flame to tilt, thus allowing the flame to move further downwind. This results in higher downwind radiation flux levels than those attained under low wind conditions. All four studies used similar atmospheric conditions for pool fire modeling.

3.3 Vapor Cloud Dispersion Parameters

Pool Evaporation

In the case of vapor cloud dispersion, pool vaporization rate is one of the most critical parameters in estimating the hazard zone distance since it determines the mass that enters into the dispersion. The approaches used in the four studies for pool evaporation are quite different and this is an area that needs further improvement.

Table 6 shows the evaporation flux used in the different studies. Evaporation flux decides the amount of material that goes in to the vapor cloud dispersion calculations and this depends on the size of the pool.

Study	Source	Pool Size Used	Evaporation Flux ($kg/m^2/s$)
DNV	Dodge et al. method	Steady state pool size	0.182 (based on steady state evaporation rate)
ABS	Webber's method	Maximum pool size	0.072 (based on maximum evaporation rate)
Sandia	Vulcan CFD model has built in spreading model.	Maximum pool size	Not Available
Quest	Mechanism not known but includes wave effect.	Not Available	0.2 (based on maximum evaporation rate)

Table 6. Pool Spreading and Evaporation

As shown in Table 6, the evaporation flux used in dispersion modeling is quite varying. ABS and Quest used evaporation flux based on the maximum values, while DNV used the evaporation flux based on steady state value.

It should be noted that the amount of material that goes into the atmospheric dispersion is also dependent on the size of the pool. Therefore, the higher evaporation flux does not necessarily mean greater evaporation from the pool. When DNV's evaporation rate is re-estimated based on the maximum pool, the evaporation flux gets closer to the values reported by ABS.

The evaporation rate calculated based on the flux and pool size reported show that DNV's evaporation rate is little bit higher than ABS's value.

Atmospheric Conditions

In case of dispersion, an unstable atmospheric condition (higher wind speed) causes more turbulence and in turn results in quicker dilution of the hazardous material. In a stable atmospheric condition (lower wind speed), the hazard zone distances usually increase due to reduced mixing of hazardous materials in the air.

All four studies used similar atmospheric conditions for dispersion analysis as shown in Table 7.

Study	Atmospheric Stability and Wind Speed	Surface Roughness Length	Relative Humidity
DNV	F-2, D-3 ,D-5 m/s	0.3 mm	70 %
ABS	F-2, D-3 m/s	10 mm	50 %
Sandia	F-2.33 m/s	0.2 mm	Not available
Quest	F 1.5 ,D-5 m/s	Not available	70 %

Table 7. Atmospheric Conditions

Surface Roughness Length

The surface roughness length describes the roughness of the surface over which the cloud disperses. It alters wind velocity profile and consequently affects the dispersion result significantly. Therefore, it is important that proper roughness lengths are used in the dispersion analysis.

Review of the four studies shows that the roughness length values used in the different studies are quite varying. DNV and Sandia used a roughness length of 0.2 mm to 0.3 mm, while ABS used 10 mm.

According to literature, the roughness lengths of open sea are 0.1 mm to 1.0 mm, depending on weather conditions (Ermak, 1990) (EPA, 1995) (EPA, 2004). Therefore, the values used by DNV and Sandia are more appropriate than a value used by ABS for dispersion over open sea.

The surface roughness used in the four different studies is presented above in Table 7 for comparison.

Relative Humidity

The humidity is used in the dispersion calculations to determine the properties of the atmosphere (mainly the density of the air) and the density of the cloud. The higher the humidity, the sooner the plume becomes buoyant due to the heat transfer from moisture. Therefore, the hazard zone distance decreases with increased humidity.

The humidity varies a lot depending on the site location. Therefore, it is best to use the site specific data for humidity, particularly in cases where the site is located in an extremely humid or dry location. In open sea, the relative humidity is normally 70% or higher.

The atmospheric conditions used in the four different studies are presented in Table 7 for comparison.

4. SENSITIVITY ANALYSIS

In order to investigate the effect of different modeling parameters on the consequence results, a few sensitivity runs were performed.

Pool Fire

The pool fire scenario of 1 m hole reported by ABS was modelled using DNV's PHAST program, with same pool radii as ABS and by setting the burning rate, surface emissive power and wind-speed equal to the ABS value. The same modeling was performed using PHAST for pool fire scenario of 1.12 m reported by Sandia and the results are shown in Figure 4 and Figure 5.

The result clearly shows a drastic reduction in the deviation of ABS and Sandia's results from the DNV value for the same hole size. The circled points show the change in ABS and Sandia values. At this stage, there is still a small deviation in results between ABS and DNV after fixing the parameters and this difference can be clearly attributed to the difference in the consequence models used in these studies. However, the DNV and Sandia results become almost the same when the same modeling parameters are used.

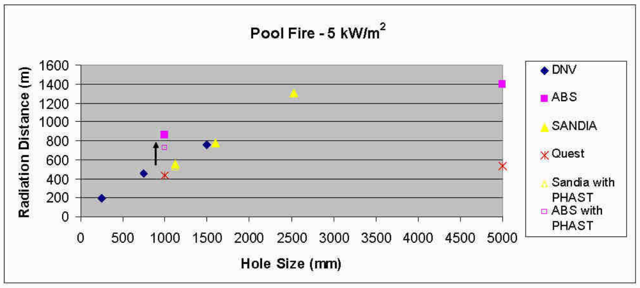

Figure 4. 5 kW/m^2 Sensitivity Run

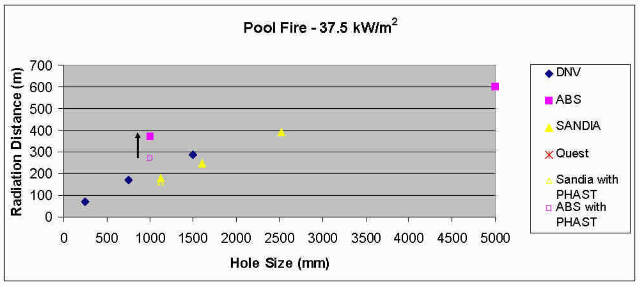

Figure 5. 37.5 kW/m^2 Sensitivity Run

Dispersion

For the dispersion modeling, ABS and Sandia cases were modeled using DNV's PHAST program by fixing the evaporation rate and atmospheric conditions such as surface roughness, relative humidity, stability wind speeds.

The dispersion scenarios of 1m hole reported by ABS and 1.12 m hole reported by Sandia were modeled using SAFETI and the result is presented in Figure 6.

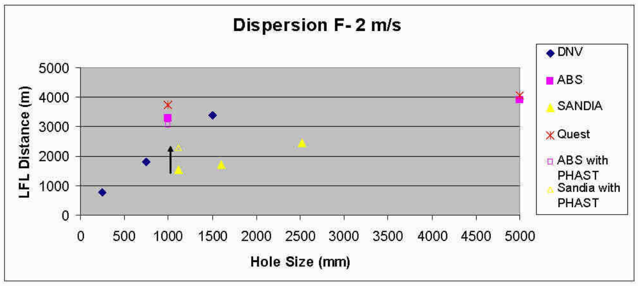

Figure 6. Dispersion Results Sensitivity Run

As shown in Figure 6, the dispersion case re-runs also showed a reduction in the deviation of results when the same modeling parameters are used. The DNV and ABS results become almost the same when the same modeling parameters are used. However, there is still a quite large deviation in results between DNV and Sandia even though the same modeling parameters are used.

This difference can be clearly attributed to the difference in the consequence models used in these studies. Sandia used a CFD code in the dispersion calculation, while others used similarity models. In order to answer whether this difference in results is due to the difference between similarity and CFD codes, further study is required.

5. CONCLUSIONS

The detailed investigation for consequence modeling approaches of recent studies shows that the varying results are due to the differences in modeling assumptions and the modeling tools used in estimating the hazard zone distances. The deviation in results between the studies reduces significantly when the same modeling assumptions are used. Therefore selection of the appropriate modeling parameters is a critical step in consequence modeling.

Further, the deviation of dispersion results between Sandia and others were significant. It may be due to the difference between models used (CFD vs. similarity). However, further study is required to confirm this.

Moreover, the scales of LNG releases modeled in these studies are much less than the scale of existing field experimental data. Therefore, additional large scale experiments will provide more confidence in the modeling methods. However, that should not prevent valid decision making today, since uncertainties that exist here are no worse than the uncertainties in many other high hazard activities.

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BROADWATER

Response to U.S Coast Guard

Letter of February 16, 2006

Codes and Standards Development

Broadwater Energy LLC

March 10, 2006

PUBLIC

1.0 Background

Compliance with applicable codes and standards is of paramount importance to ensuring a safe and reliable facility design. To ensure that appropriate codes, regulations and standards are applied to the design, construction and operation of the facility, the Floating Storage and Regasification Unit and associated mooring has been characterized as essentially an LNG carrier, with additional regasification equipment, moored at a fixed location.

Given the marine nature of the proposed facility and its similarities with LNG carrier design and operation, a ship classification society will be involved in the oversight throughout the project design and construction process. Classification societies are organizations that establish and apply technical standards in relation to the design and construction of marine-related facilities, including ships and offshore structures. These standards are issued by the classification society as published Rules. As an independent, self-regulating body, a classification society has no commercial interests related to ship design, building, ownership, operation, management, maintenance or repairs, insurance or chartering. In establishing its Rules, each classification society may draw upon the advice of members of the industry who are considered expert in their field. Classification societies also maintain significant research departments that contribute towards the ongoing development of appropriate, advanced technical standards.

LNG carrier design, construction, and operation are comprehensively covered by rules and guidelines and the legislative requirements of national and international authorities. An LNG carrier is typically constructed according to "Classification Society Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk," also known as the Gas Ship Rules. Compliance with the Gas Ship Rules is ensured through design appraisal and survey during building and commissioning. Although legislative requirements are not, strictly speaking, a classification issue, it is usual for the classification society to make compliance with legislative requirements a prerequisite for compliance with its Rules.

Classification Society Gas Ship Rules incorporate the requirements of the International Maritime Organization's *International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk* (generally known as the IGC Code). The IGC Code is a *de facto* international standard by virtue of its adoption by the industry and regulatory bodies.

For this project, an extensive array of standards have been assembled based on federal and state standards, classification society Rules, and, as appropriate, international standards for design and construction that incorporate appropriate federal, state, national and international requirements.

Broadwater engaged the services of the American Bureau of Shipping (ABS), one of the world's leading ship classification societies, to ensure that all applicable standards are incorporated within the facility design. On July 27, 2005, Broadwater received an

"Approval in Principle" for the Broadwater FSRU from ABS, based on its review of the conceptual design.

2.0 Description of Codes and Standards Selection Process

The selection of the appropriate codes and standards evolved during the technical development of the FSRU. The resultant design is documented in Resource Report 13. Within each section of Resource Report 13 which deals with a major equipment item, the applicable codes and standards used to guide the design process are documented.

The process adopted for codes and standards selection is outlined in the attached flowchart, of which an integral component was the design review activities completed by the American Bureau of Shipping (ABS).

Selection of the project codes and standards was initiated by Broadwater Energy at the start of concept design development, when a Basis of Design Document was prepared. At this stage the technical advisors to the Broadwater project (Shell Global Solutions US), which included a broad range of discipline engineers, proposed indicative codes and standards that would normally be considered appropriate based on their experience of preparing design documents and specifications for both onshore and marine projects.

In the first quarter of 2005, Broadwater selected engineering contractors (including hull, containment, LNG process and mooring system disciplines) to complete the initial design of the facility. These contactors then reviewed and appended as considered appropriate the preliminary list of codes and standards which formed the basis for the detailed listing in Resource Report 13. Broadwater deliberately selected these contractors on the basis of their global expertise in their respective fields:

(1) Samsung Heavy Industries, which is an experienced shipbuilder, for its ability to design and construct LNG Carriers and expertise with hull, LNG membrane containment and in-hull systems;
(2) Saipem America Inc. which has experience with onshore LNG terminal projects and offshore engineering; and
(3) SBM-IMODCO, Inc., which is one of the world leaders in mooring systems and FPSO (Floating, Production, Storage and Offtake) systems.

By combining these capabilities within a review of the standards, the managing contractor, Saipem, was able to confirm compatibility between the hull, topside process equipment and yoke mooring components of the project, as well as the related codes and standards to be applied.

Broadwater Energy met with the USCG and FERC representatives on June 29, 2005 and a document entitled "*Resource Report 13 – Indicative Codes and Standards*" was left with the agencies to provide an indication of the direction that Broadwater proposed to take with respect to this issue.

A draft version of Resource Report 13, including Section 13.12 (Design Codes and Standards) and related Appendices, was submitted to ABS for review to permit its issuance of an Approval in Principle for the LNG import facility concept.

A key element of ABS' Approval in Principle was its review against the criteria specified in its *Guidance Notes on Review and Approval of Novel Concepts* dated June 2003. ABS requires applicants to provide "Support Information" which is identified in its Guidance Notes as:

> "(i) List of reference codes and standards to be applied to the application and the technical justification for selection of those standards if not readily apparent." (Page 17)

ABS issued its Approval in Principle Letter on July 27, 2005. ABS goes further in its issued Approval in Principle to make clear that the technologies employed are not in themselves novel, and are covered by established Rule criteria.

Broadwater Energy has defined in its FERC application that appropriate marine standards such as IMO Codes and classification society Rules will apply for the hull, LNG containment system and ship related systems; and that standards normally considered appropriate to land-based terminals would be applied to the extent practicable for the LNG regasification plant and related process systems operating in an offshore floating environment. This approach is consistent both with ABS' *Guidance Notes on Review and Approval of Novel Concepts* (June 2003) and the *Guide for Building and Classing Offshore LNG Terminals* (April 2004).

Attached is a letter and related material from ABS, dated March 9, 2006 which details the involvement of ABS in the review of codes and standards for the project.

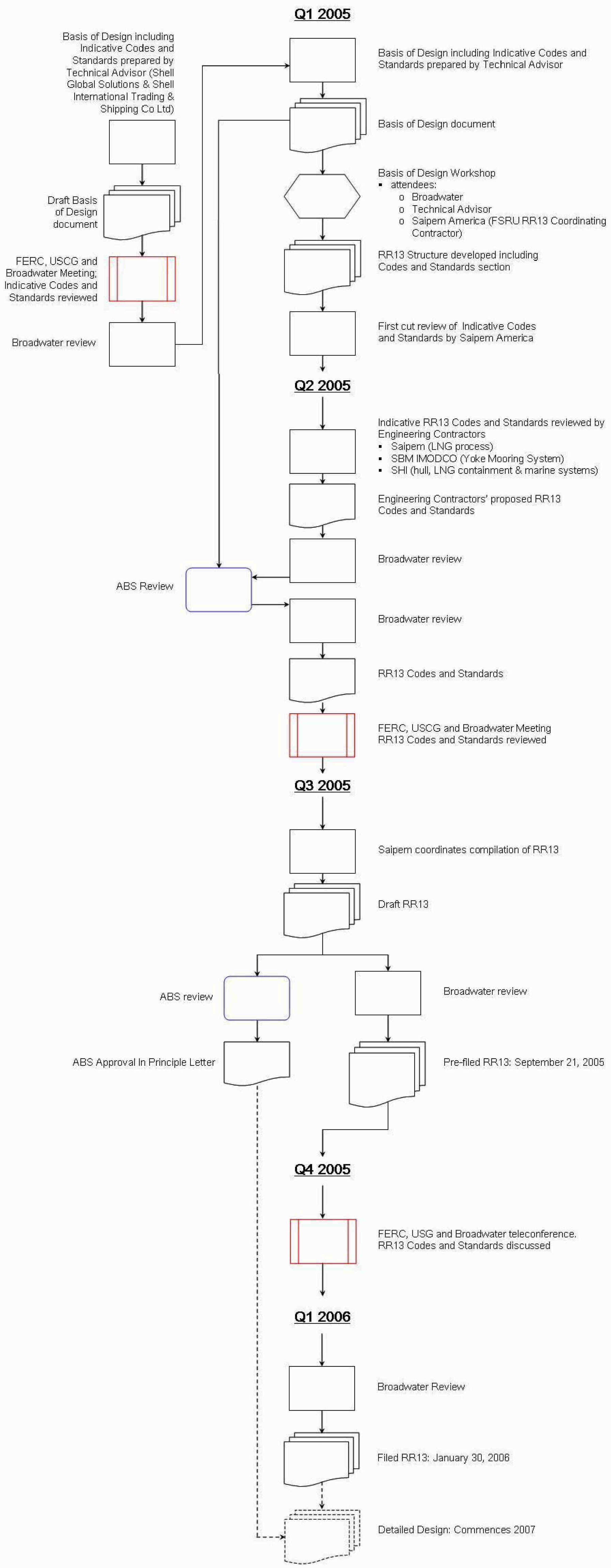
In its review of the codes and standards for the proposed facility, Broadwater has addressed issues of the appropriateness of overlapping codes and standards, and selected whichever applicable code or standard is more stringent. Two such examples are described as follows:

1. Resource Report 13, Section13.14 (Regulatory Compliance) that discusses the application of traditional land-based regulations, as outlined in 49 CFR 193 and NFPA 59A, to an offshore floating environment. The relevance of each section has been analyzed and the results documented in this section.

2. The proposed design for the Yoke Mooring System is an example of the selection of a more stringent design criterion. The normal design for an offshore structure is based on environmental criteria with a 1:100 year return period (a return period is the frequency with which an event would be expected, on average, to recur). The 1938 hurricane affecting Long Island Sound was classed as a Category 3 or 4 hurricane, but in design terms would have only been considered a 1:50 year event.

Broadwater chose an extremely conservative design significantly in excess of the 1:100 year standard. The specified extreme 1 hour average wind speed of 56.8 m/s (approximately 110 knots or 127 miles per hour) was chosen, based on analysis of historical wind data in the region. This design criterion is for an average 1 hour wind speed, which differs from the Saffir-Simpson Hurricane Scale, which is based on wind speeds of 1 minute average duration. When converted using available Gust Factor Curves, this aligns with a 1 minute average wind speed of 88.5 m/s (approximately 172 knots or 198 miles per hour), which is substantially in excess of the minimum wind speed for a Category 5 hurricane (winds greater than 155 miles per hour). Only three Category 5 hurricanes have made landfall in the United States since records began, all of these occurring in the southern U.S. A Category 5 hurricane has never been experienced in the vicinity of Long Island Sound.

RR13 Selection of FSRU Codes & Standards



Broadwater Energy – March 13, 2006; REV 1

FOUNDED 1862

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9 March 2006

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For the attention of Mr.W. Gray, Technical Manger

ABS Involvement
Broadwater Project

Dear Sir,

Further to recent correspondence we are pleased to confirm the extent and involvement of the American Bureau of Shipping (ABS) with the Broadwater Project.

The timetable and extent of ABS involvement has been agreed and documented in various flowcharts indicating project milestones from Q1/2005 onwards (it is noted that the initial ABS Meeting with Broadwater Team members was actually held in November 2004). ABS "scope of work" related to the Broadwater Project was documented in our "ABS Approval-in-Principle (AIP) for LNG FSRU / Gas Import Facility" Revisions 0 and 1, dated March 2005.

The methodology applied by the ABS Team in coming up with the deliverables agreed in the terms of the AIP proposals was consistent with the processes described in our publication "ABS Guidance Notes on Review and Approval of Novel Concepts", June 2003 – details of the publication are attached as Appendix "A" to this letter. The constitution of the ABS Team working on the Team was documented in the provided "ABS Review Team Organization" diagram. – attached as Appendix "B" to this letter; all members of the ABS Team were suitably qualified and knowledgeable for the part or parts reviewed and commented upon as required by our internal processes in accordance with the ABS ISO 9001, externally issued certification.

ABS confirms that it was satisfied that due consideration of standards and Codes had been made by the Broadwater Team during "basic design" process and was comfortable with respect to the use of the individual proposed components of the project in the intended project execution upon further development towards final project final design.

AMERICAS DIVISION

The general premise that the Broadwater Team were intending to apply proven technology from the marine and gas transportation industries was noted throughout the ABS involvement and our focus in reviewing the overall project was with respect the degree of novelty of the individual components in their specific and intended application. The ABS review process was completed with no major comments and the AIP letter was issued on or around 27th July 2005.

The application of Classification requirements and systematics during future stages of the project provide a clear path to proceed with as far as the marine aspects of the project are concerned and ABS are confident that they would be able to complete Classification process for the project in compliance with our published Rules and Guides; compliance with other performance standards, additional to those required by Class process, may additionally be confirmed by ABS during design, fabrication and installation/commissioning stages of the project as they occur.

We hope the foregoing meets your needs at this time; should additional details or information be required please do not hesitate to contact the undersigned or:

Mr. Phillip Rynn:– Senior Staff Consultant (Broadwater AIP Project Manager)
Tel: 281-877-6415

or

Mr. Harish Patel - Principal Engineer (Broadwater AIP Asst. Project Manager)
Tel:- 281-877-6469

We wish everyone a safe and successful project. Thank you for the trust you have placed in ABS at this time.

Very truly yours,
William J. Sember
Vice President

By: Ian A. Simpson

Ian A. Simpson
Manager - Energy Project Development

Attachments Appendix "A"
Appendix "B"

APPENDIX “A”

ABS Novel Concepts Guidelines

Motivation for Guide

- Many new offshore and marine concepts being proposed by industry
  - GTL FPSOs
  - LNG FPSOs
  - CNG Carriers
  - Floating and Fixed Base Gas Terminals
  - New Types of Offloading Systems
  - Use of composites

- Need to provide a general road map to client's on how ABS will evaluate and approve proposed novel concepts or applications

Key Aspects of Guide

- Outlines an ABS process to obtaining Class Approval for a Novel Concept
- Includes an intermediate step covering Approval In Principle
- Requires ABS and its clients to agree on the appropriate risk and engineering analysis techniques and justification to be employed
- Enables both Client and ABS to demonstrate the methodology used to establish fitness for purpose

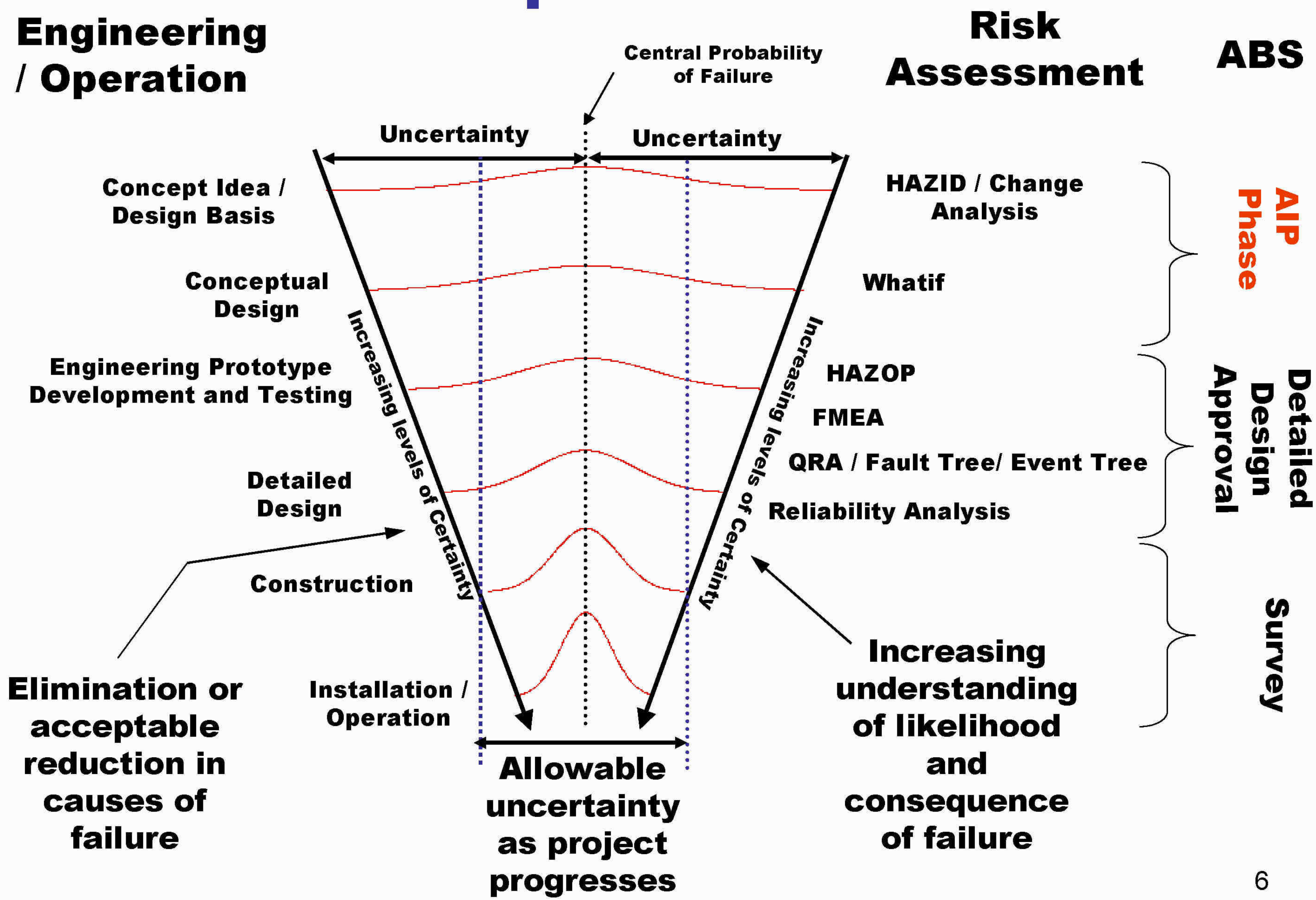
Guidance Note Outline

- Objective
- Definitions
- Applicability - checklist approach
- Process to obtain Approval In Principle (AIP)
  - Documentation to be submitted
  - Concept Engineering Evaluation
  - Concept Risk Assessments
- Process to Full Class Approval
  - Documentation to be submitted
  - Design Evaluation
  - Risk Assessments
- Special Consideration for Maintenance of Class

Guidance Notes Objectives

- Provide guidance to ABS clients related to the ABS methodology for review and approval of novel concepts
- Provide process and responsibilities for ABS review of proposed novel concepts from the project concept stage through maintaining Classification.
- Outline documentation requirements

Concept Evolution



Key Definitions

- Novel Concept: A design or process that has no previous experience in the environment being proposed.

- Approval in Principle (AIP): Process by which ABS issues a statement that a proposed concept design complies with the intent of ABS Rules and/or appropriate codes, subject to a list of conditions that must be addressed in the final design stage.

Key Definitions

- Classification is a representation by ABS as to the fitness for a particular use or service in accordance with its Rules and standards. For *novel concept*, this would also mean that the conditions outlined within the approval road map identified during the AIP stage have been demonstrated to the satisfaction of ABS.
- Maintenance of Classification: The fulfillment of the requirements for surveys after construction. For *novel concept*, this would mean all requirements within the applicable ABS Rules, plus any additional requirements outlined in the conditions of class for the concept.

Guide Applicability

- Define when use of this guideline is appropriate
- Guideline meant to help identify:
  - Existing design/process/procedure in new or novel application or when challenging boundaries/envelope of current applications
  - Existing design / process / procedures challenging the present boundaries/envelope of current offshore or marine applications.
  - New or novel design / process / procedures in existing applications
- Checklist approach - if answers to queries is "yes", then this guideline may apply.

Applicability Checklists

- Questions related to system broken up into categories
  - Stationkeeping
  - Marine
  - Structural
  - Process
  - Cargo/Storage
  - Other (e.g., concept not directly covered under Class but the performance of that system could impact vessel structural integrity, stability or safety of the classed components)

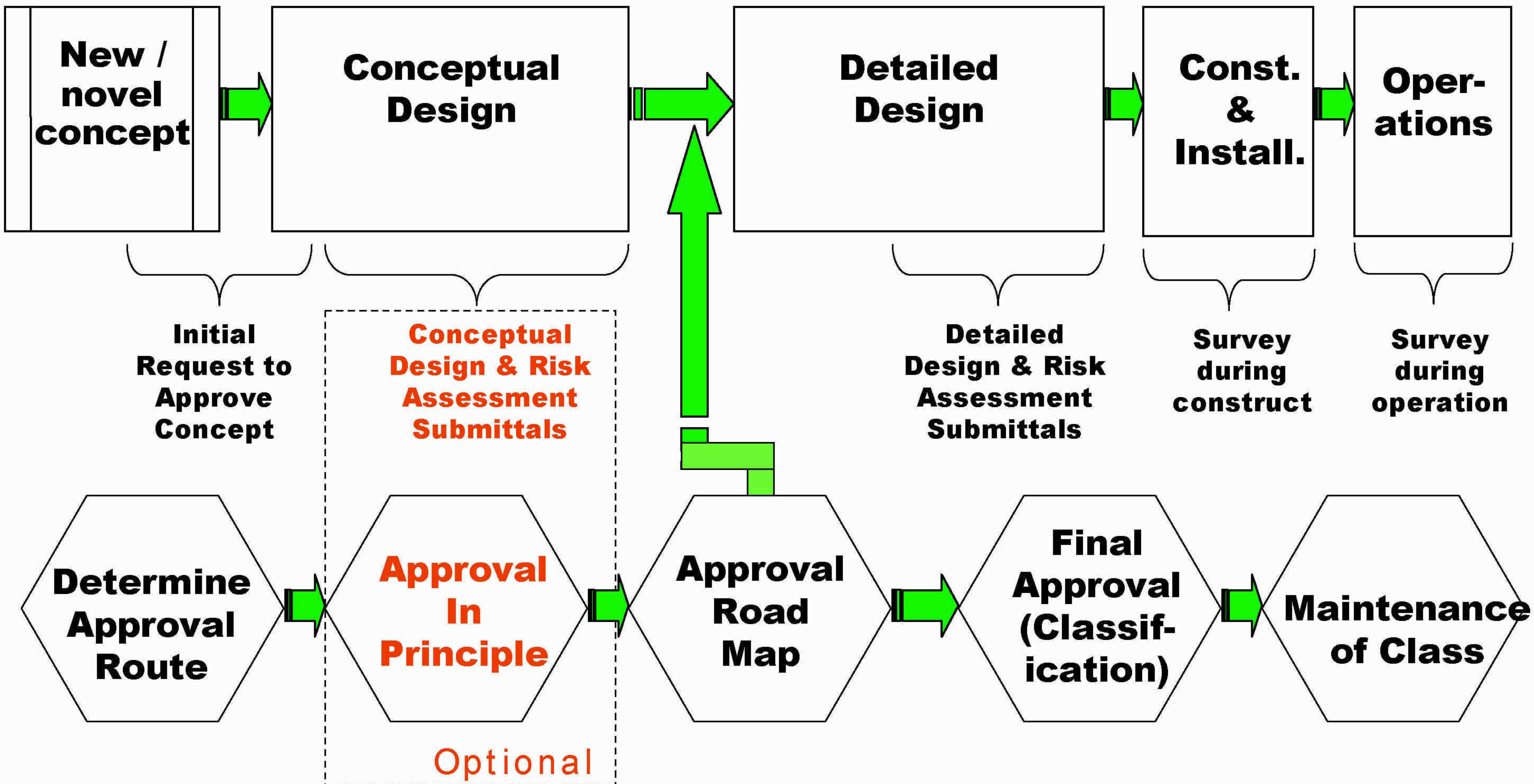
Applicability Checklists

- Example Questions
  - Is the vessel or offshore facility design basis considered within current experience boundaries for this application?
  - Are there marine or *offshore* applications of the proposed storage systems that will be on the vessel or offshore facility?
  - Are there existing *onshore* applications of the proposed storage systems that will be on the vessel or offshore facility?
  - Are there any *existing commercial applications* of the proposed storage systems similar to that which will be used on the vessel or offshore facility?

Approval Process Approach

- Provide ABS clients with a consistent evaluation approach for novel concepts
  - requires ABS and its clients to agree on appropriate engineering assessments to be conducted for **AIP** and Class
  - requires ABS and its clients to agree on appropriate risk analyses to be employed and when they should be applied for **AIP** and Class
  - requires ABS and its clients to agree on appropriate data collection and testing to be carried out to assist in proving the technology for **AIP** and Class

Approval Process Flowchart



Determine Approval Route

- Initial discussions between client and ABS on proposed concept
  - ABS gains general understanding of concept
  - Determine if AIP route will be taken
- If AIP route taken
  - Agree upon most appropriate plan for achieving AIP.
  - Outline the necessary engineering and risk assessments to be conducted on the novel features
  - Agree upon appropriate to the level of design evolution expected in the conceptual design stage in order to achieve AIP.

Approval In Principle

- Concept Engineering Evaluation:
  - Verify that the design is feasible in all phases of operation (such as in-transit, installation, commissioning, and operation for an offshore application) as far as practical within the concept phase.
  - Concept Design Verification
    - Conventional Features
    - Novel Features
    - Operability
    - Interface Issues
    - Inspectability and Maintainability

Approval In Principle

- Concept Risk Assessments:
  - At a minimum, a qualitative risk assessment (e.g., HAZID) will be conducted to identify all potential failure scenarios and associated risks (i.e., generate Hazard Register)
  - Following the qualitative risk assessment an agreed upon Risk Assessment Plan (roadmap) will be developed and carry forward into Full Approval Phase
  - Roadmap will
    - Address findings of Hazard Register
    - Identify additional detailed risk assessments, as required

Approval In Principle Conditions

- Concept engineering evaluations and risk assessments did not identified any "showstoppers"
  - No abnormal hazards
  - No excessively onerous failure mode
- Concept deemed suitable for use within a marine or offshore environment without the need for excessive or onerous monitoring during operation or maintenance/inspection considered atypical for such applications.

Approval Road Map

- Design Assessment Plan:
  - Describes the proposed means of justification for all relevant features of the novel application, their associated failure modes, and the means proposed to assess the engineering suitability
  - Outlines how consensus will be reached for what is deemed to be acceptable results for the design analyses
  - Identifies required steps to be taken in the concept evaluation as well as in the full approval phase

Approval Road Map

- Risk Assessment Plan:
  - Identifies the appropriate type of assessment techniques for the AIP phase and full approval phase
  - Describes how the team envisions a holistic approach to risk assessment for all phases of the concept development
  - Identifies how consensus will be reached on risk acceptance criteria
  - Understanding that as the team gains knowledge of the application, modifications to plan may be warranted

Full Class Approval

- Engineering Review and Verification of Design:
  - Reconfirmation of Relevant Design Codes and Standards Applied
  - Calculation Dossier
  - Confirmation of Interface Issues
  - Confirmation of Inspectability and Maintainability
- Specifies submittal requirements related to novel concept

Full Class Approval

- Detailed Risk Assessments:
  - Quantitative risk methods
    - Types (Event Trees, Fault Trees, Structural Reliability)
    - Uses and limitations
    - Submittal requirements prior to initiating risk assessments
  - Selection of target reliability and risk acceptance criteria
    - Difficulties in criteria selection for novel concepts
    - Backup and justification requirements prior to accepting risk acceptance criteria
  - Comparative risk assessments
  - Risk submittal requirements
- Review of Hazard Register to ensure all identified hazard addressed
- Review of final design to ensure no new hazards created

Survey/Maintenance of Class

- Input to Survey During Construction
  - Critical Areas
  - Verification and Witness of Testing
- Input to Survey During In-Service Operation
  - Maintenance schedules
  - Inspection scope/frequency
  - Conditional failure probabilities
  - Pilot Testing of Novel Features

Broadwater Energy **ABS Review Team Organization** 18MAR05

APPENDIX "B"